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(54) Improvements in or relating to MOS-FET differential amplifiers

(57) A MOS-FET differential amplifier with two field effect transistors T11, T12 has two Zener diodes, D11, D12, provided to protect the gate electrodes from static charges. These Zener diodes are arranged with mutually opposed polarity in a series path between the gate electrodes, and are only coupled to the substrate via a feedback arm of an amplifier transistor T13 connected in the output path. This results in the gate electrodes not being subjected to the gate-source voltage, but merely to the offset voltage between the two field effect transistors.

Fig.2

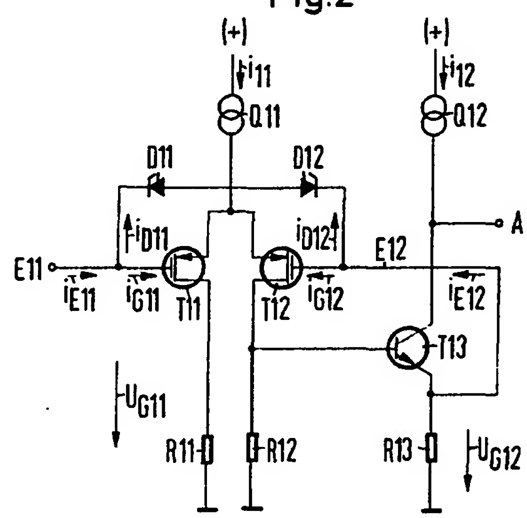

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Fig.1

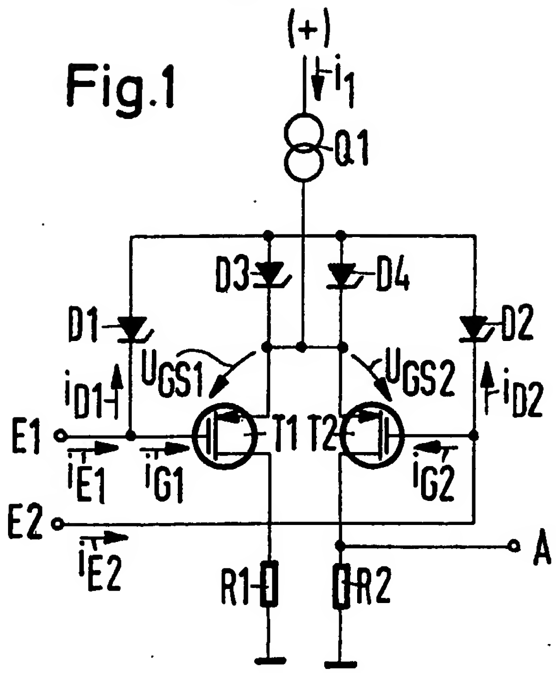
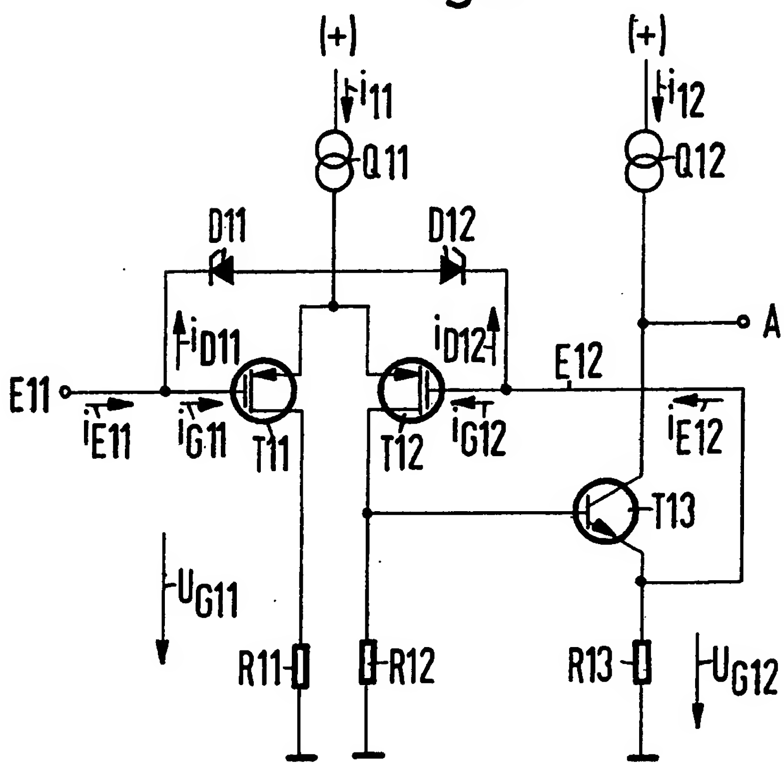

(+)
i_1
Q1
D3
D4
D1
D2
U_{GS1}
U_{GS2}
i_{D1}
i_{D2}
E1
T1
T2
i_{E1}
i_{G1}
i_{G2}
E2
i_{E2}
A
R1
R2

Fig.2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i_{11}
Q11
(+)
i_{12}
Q12
D11
D12
i_{D11}
i_{D12}
A
E12
E11
i_{E11}
i_{G11}
T11
T12
i_{G12}
i_{E12}
T13
U_{G11}
R11
R12
R13
U_{G12}

SPECIFICATION

Improv ments in r relating to MOS-FET differential amplifiers

The invention relates to MOS-FET differential amplifiers consisting of two field effect transistors which are connected in parallel to be fed via a common constant current source connected to their respective source electrodes, a respective input signal terminal being connected to the gate electrode of each field effect transistor, and an output signal terminal being connected to the drain electrode of one of the field effect transistors, and a diode protection circuit being provided for the respective gate electrodes of the two field effect transistors.

It is known to form differential amplifiers comprising MOS field effect transistors as integrated circuit modules. MOS-FET type transistors can be destroyed very easily by any parasitic voltage at the gate electrode, such as may result from static charges or from physical contact. In order to avoid damage of this type it is now a normal practice to integrate the field effect transistors together with additional diode structures which protect the gate from reaching a high potential relative to the substrate. Any discrete MOS field effect transistor may have a Zener diode provided between its gate electrode and the substrate for this purpose. When the substrate is externally connected to the source electrode, the gate is protected from the source electrode via the diode. In known differential amplifiers having a MOS-FET input stage, the normal practice is to use diode structures which are connected between the gate electrodes and the source electrodes. However, this has a disadvantage, as these diodes may pass blocking currents which are temperature dependent and are a function of any voltage applied to the diodes. On account of the relatively high voltage between gate and source, correspondingly high blocking currents may flow. These are superimposed upon the much smaller input currents of the MOS-FET type transistors, thus reducing the overall input impedance.

One object of the present invention is to provide a circuit for a differential amplifier which ensures a reliable protection of the gate electrodes from static charges whilst ensuring a high input impedance.

The invention consists in a MOS-FET differential amplifier, in which two field effect transistors which are connected in parallel with their source electrodes linked to a common constant current source, an input signal terminal being connected to the gate electrode of a first one of said field effect transistors, and an output signal being taken from the drain lectrode of the second one of said field effect transistors, which signal is f d back via an amplifier transistor to the gate electrode of the second field effect transist r, a diode protective circuit being provided f r the gate electrodes of the two field ff ct transistors, which protective circuit consists of two Zener diodes connected with mutually opp sing polarity in a series path between the gat el ctrod s of the two field effect transistors their only c nnection to the substrat being via the feedback arm and an emitter resistor of the amplifier transistor.

In an exemplary embodiment of the invention, as the protective diodes are not subjected to the gate-source voltage but to the considerably smaller offset voltage between the two input transistors, the input current of the amplifier is considerably reduced. Thus the protective function is produced by the two Zener diodes in association with the emitter resistance of the amplifier transistor.

The invention will now be described with reference to the drawings, in which:—

Figure 1 is a schematic circuit diagram of one known, integrated differential amplifier with a MOS-FET input stage; and

Figure 2 illustrates the circuit of one exemplary embodiment of a differential amplifier constructed in accordance with the invention.

The known circuit illustrated in Figure 1 is of a commercially available, integrated differential amplifier with a MOS-FET input stage. This fundamentally consists of two field effect transistors, T1 and T2, which are connected in parallel to a common constant current source Q1 by their source electrodes. Input signals can be connected to the respective gate electrodes via respective inputs E1 and E2. An output terminal A is provided from the drain electrode of the transistor T2. Respective drain resistors R1 and R2 are provided. A diode structure comprising Zener diodes D1, D2, D3 and D4 protects the inputs of the differential amplifier from excess voltages. Via the input E1 there flows an input current i_{E1} which is divided into a gate blocking current i_{G1} and a diode blocking current i_{D1}. The same conditions apply for the input E2. Consequently, the following relationships occur:

$$i_{E1} = i_{D1} + i_{G1} \text{ and}$$

$$i_{E2} = i_{D2} + i_{G2}.$$

As $i_G \ll i_D$, it follows that

$$i_{E1} \approx i_{D1} \text{ and } i_{E2} \approx i_{D2}$$

$$i_{D1} = f(U_{GS1}; T) \text{ and}$$

$$i_{D2} = f(U_{GS2}; T)$$

Thus the input current i_{E1} is dependent upon the gate-source voltage U_{GS1} and the input current i_{E2} is dependent upon the gate-source voltage U_{GS2}. Both are additionally dependent upon the temperature. For example when a differential amplifier f this kind is used in an ionisation fire alarm, this can lead to th measurement being unreliably adulterated at a high temperature.

An exemplary embodiment of a differential amplifier c nstructed in accordance with the invention, shown in Figure 2, has an input current

which is considerably lower than in the case of Figure 1. Two field effect transistors T11 and T12 are c nnected to a common c nstant current s urce Q11 and respective drain resistors, R11 and R12 are provid d. The input signal is fed via an input E11 to the gate electrode of the first transistor T11. The output is taken from the drain of the second transistor T12 to the base of an amplifier transistor T13 whose emitter path contains a resistor R13, and the emitter electrode is connected to provide feed back via an input E12 to the gate electrode of the second field effect transistor T12. The output signal can be fed to an output terminal A from the collector of the amplifier transistor T13, the collector path including a load which in this case takes the form of a further constant current source Q12.

Two Zener diodes D11 and D12 are provided in order to protect the inputs of the field effect transistors T11 and T12. However, in contrast to Figure 1 these Zener diodes are connected with mutually opposed polarity in a series path directly between the two gate electrodes of the differential amplifier, so that they do not carry the gate-source voltage but merely the considerably lower offset voltage of the two field effect transistors, as the only connection to the substrate is via the feed-back path and the resistor R13.

Consequently the following relationships occurs:—

$$i_{E11} = i_{D11} + i_{G11}$$

As $_G \ll i_D$, we have $i_{E11} \approx i_{D11}$.

Then $i_{D11} = f\,(U_{G11} - U_{G12};\, T)$

$$U_{G11} - U_{G12} = U_{offset}$$

$$i_{D11} = f\,(U_{offset};\, T)$$

$$i_{E11} = f\,(U_{offset};\, T)$$

As $U_{offset} < U_{GS}$, we hav $i_{E11} < i_{E1}$.

In the built-up state, the diff rence between the two gate voltages U_{G11} and U_{G12} is qual to the offset voltage U_{offset} of the pair of input transistors, and is consequently very small. The protective diodes are subjected to a very small voltage which also results in a very small diode blocking current. If the gate voltage U_{G11} becomes smaller, the current across the transistor T11 increases and the current across the transistor T12 reduces. Consequently there is also a reduction in the voltage drop across the resistor R12, the resistance presented by the amplifier transistor T13 becomes higher, and the feedback voltage U_{G12} also reduces until the relationship $U_{G11} - U_{G12} = U_{offset}$ is fulfilled.

CLAIMS

1. A MOS-FET differential amplifier, in which two field effect transistors which are connected in parallel with their source electrodes linked to a common constant current source, an input signal terminal being connected to the gate electrode of a first one of said field effect transistors and an output signal being taken from the drain electrode of the second one of said field effect transistors, which signal is fed back via an amplifier transistor to the gate electrode of the second field effect transistor, a diode protective circuit being provided for the gate electrodes of the two field effect transistors, which protective circuit consists of two Zener diodes connected with mutually opposing polarity in a series path between the gate electrodes of the two field effect transistors their only connection to the substrate being via the feedback arm and an emitter resistor of the amplifier transistor.

2. A MOS-FET differential amplifier substantially as described with reference to Figure 2.

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